BEAUMONT
TEXAS

February 8, 2022

ADDENDUM NO. 1

BID FOR: **Collier's Ferry Pump Station Project**

BID NO.: **WU0222-14**

1. The following additions, deletions, modifications, or clarifications shall be made to the appropriate sections of the plans and specifications and shall become part of the Contract Documents.

2. All bidders are herewith notified of the following additions, deletions, changes, or clarifications to the original Specifications, Contract Documents, and Contract Drawings:

   ADDITIONS:

   A. Clemson Engineering Hydraulics (CEH) Study
      1. City of Beaumont Intake Pump Station – Physical Hydraulic Model Study Final Report

   Response to CIVCAST Questions and Clarifications:

   Q1. Is an Engineer's Estimate available for this project?
   A1. Engineer's Estimate: $25,282.100.00

3. **When submitting bid, bidders, MUST acknowledge receipt of this Addendum No. 1 on the appropriate page within the bid specifications.**

If we can be of further service, please do not hesitate to call John Pippins, Water Utilities Design Manager at 409-785-4702.

Sincerely,

Amalia Villarreal

Amalia "Molly" Villarreal, P.E.
City Engineer

END OF ADDENDUM NO. 1

CITY UTILITIES
T 409.866.0026
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beaumonttexas.gov

CITY OF BEAUMONT
INTAKE PUMP STATION

PHYSICAL HYDRAULIC MODEL STUDY

Final Report

Conducted For

Freese & Nichols

CEH Report No. 945-21

November, 2021

CLEMSON ENGINEERING HYDRAULICS, INC.
1203 River Heights Circle • Anderson, SC 29621
864.231.9585

CITY OF BEAUMONT
INTAKE PUMP STATION

PHYSICAL HYDRAULIC MODEL STUDY

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November, 2021

Prepared by:

Matthew Havice, P.E.
Project Engineer

Approved by:

David E. Werth. Ph.D., P.E.
Principal Engineer

EXECUTIVE SUMMARY

A 1:5.5 scale physical model of the Beaumont pump intake structure was constructed, and tests were conducted to determine the nature and severity of any adverse hydraulic conditions that may affect pump performance.

Initial testing showed that overall conditions in the trough baffle and in the wet well were turbulent and unstable. With no flow over the top of the vertical trough wall, all flow had to pass through the floor openings, which resulted in accelerated, high velocity flow on the floor approaching the pumps. The high velocity approach flow on the floor passed under the pumps and lifted vertically upward once behind the pumps. This phenomenon was observed for all operating conditions (1-3 pumps in operation). Stable, well developed floor vortex activity was observed under the pumps. Intermittent mid-flow vortex activity was observed forming between pumps when adjacent pumps were operating. Intermittent sidewall vortex activity was also observed forming on the curved outer walls adjacent to the outer pumps. Overall pre-swirl values were elevated and unstable, with frequent stalling and burst swirl observed.

Baseline testing indicated that submerged vortex activity and accelerated flow on the wet well floor were the two main hydraulic issues that required mitigation. Floor cones were installed under the pumps and were effective at preventing floor vortex activity. In addition, dividing floor splitters were installed in between the pumps and sidewall fillets were installed on the curved outer wet well walls adjacent to the outer pumps. The fillets and splitters were effective at preventing both sidewall and mid flow vortex activity. In order to reduce the approach velocity on the floor of the wet well, the vertical trough wall was revised by removing sections on each side of the wall. The center portion of wall remained unchanged. The openings on the side of the wall allowed water to pass through, thus reducing the velocity through the floor openings and the velocity on the wet well floor approaching the pumps. With the modifications installed, approach velocities on the wet well floor were significantly reduced and vortex activity was minimized.

It is recommended that the vertical trough wall be revised to allow surface flow to pass through notches cut into the sides of the wall. Floor cones should be installed under each pump. Dividing floor splitters should be installed between the pumps and sidewall fillets should be installed along the curved outer wall adjacent to the outer pumps. The recommended modifications can be seen in Figures 5-1 through 5-3.

1.0 INTRODUCTION

1.1 Background

Clemson Engineering Hydraulics, Inc. conducted a physical hydraulic model study of the City of Beaumont raw water pump intake for Freese & Nichols. The intake will house four (4) submersible pumps, each rated at 15 mgd and be housed in a circular caisson type structure. The intake will be fed via a single 48-in diameter influent pipe that supplies flow into a trough style baffle with floor openings to allow flow to pass through into the wet well.

The model was used to evaluate the hydraulic conditions within the wet well and to determine any adverse hydraulic phenomena that may exist which could adversely impact pump performance. In addition, the model was used to develop recommended modifications to remediate any adverse hydraulic phenomena, which could impact pump performance.

1.2 Objective

The objectives of this model study were as follows:

- Evaluate the performance of the intake structure to determine if any potential problems may exist with the approach flow hydraulics that may adversely impact the performance of the pumps.

- If necessary, develop modifications to the design or implement corrective measures that would mitigate or eliminate problems associated with the adverse approach flow.

- Test and document the approach flow conditions in the sump with the final recommended modifications in place.

1.3 Sump Hydraulics & Pump Problems

The pump manufacturer typically develops pump curves at the manufacturing facility. The head-flow curves, efficiencies, net positive suction head, and power requirements are usually determined by conducting a pump test with the actual prototype pump or a geometrically similar model. This pump test is conducted in a controlled environment with uniform approach flow to the pumps. Therefore, to ensure that the pump will perform as tested at the manufacturing facility; the prototype field installation must also have similarly uniform approach flow conditions.

Failure to provide uniform approach flow hydraulics can result in pump performance that differs significantly from that predicted from the performance curves. The pump may not operate at its best efficiency point, flow or head may be less than expected, power requirements may vary, and if the approach flow conditions vary enough, significant damage could occur to the pump itself.

Pump intakes are often designed to adhere to the 2018 Hydraulic Institute Standards (ANSI HI 9.8-2018). A consortium of pump manufactures, engineers, and end users developed these standards. Failure to adhere to these standards can lead to a number of problems including air entrainment, vortex activity, skewed velocity distributions and turbulence at the pump impeller. Research has shown that these conditions can lead to fluctuating loading on pump impellers, vibration, cavitation, and decreased flow and efficiency (Sweeney and Rockwell 1982).

Following the HI standards helps to minimize adverse approach flow conditions within the pump sump. However, the standards were developed for pumps with individual capacities of 40,000 gallons per minute (gpm) or less for vertical pumps, 20,000 gpm or less in trench type wet wells, 7,000 gpm or less for “can” pumps and 5,000 gpm or less for pumps in circular wet wells. When dealing with pumps that exceed these capacities, or overall station capacities in excess of 100,000 gpm, it is necessary to utilize physical and numerical modeling techniques to investigate the hydraulic conditions within the sump.

Physical models are used to evaluate the level of temporal velocity fluctuations, or turbulence, within the pump bell. Changes in pressure are directly related to changes in velocity. Therefore, velocity fluctuations, whether temporal, or as a result of skewed approach flow, can cause pressure fluctuations on the pump impeller. These pressure fluctuations translate into a loading imbalance on the pump shaft, possibly causing vibration or pre-mature bearing wear.

Physical models are also used to evaluate the uniformity of the flow within the pump bell. Should more flow be traveling down one side of a pump bay than the other, such as that which occurs when there is flow separation at the bay entrance, the velocity may be higher on one side of the impeller or the other. This may cause pre-swirl of the flow entering the pump. Depending on the direction of the pre-swirl relative to the pump rotation, this may cause the pump to consume more or less power than anticipated, resulting in the pump operating at a point other than its best efficiency. The pre-swirl may also result in the flow hitting the impeller blade at an angle of attack other than what it was designed for. This can result in localized flow separation on the impeller. These separation zones can cause low-pressure regions, which result in localized areas of cavitation.

Vortices are another hydraulic phenomenon with which physical models are used to identify and eradicate. Vortices are localized regions of high velocity swirling flow. The velocity at the core of a vortex can be high enough that the pressure falls below the vapor pressure of the fluid. If the vortex forms below the surface, it is called a submerged vortex, and can result in vapor being pulled out of suspension. If it forms as a surface vortex, it can pull a vapor core into the pump. Either of these vortices can result in air entrainment or cavitation within the pump. Depending on the system, this entrained air may be able to accumulate within the downstream piping network, possibly causing damage to other system components. The low-pressure core of a vortex can also lead to localized cavitation, noise, decreased pump capacity, and vibration.

Numerical modeling of pump sumps is a relatively new approach to investigating wet-well hydraulics. The ability of numerical models to predict the general flow patterns within the sump is constantly improving. However, numerically modeling highly mobile surface vortices presents a challenge. Research is constantly being conducted to improve the ability to numerically predict mobile vortex activity. However, at the present, physical models remain the only method available to reliably simulate mobile prototype vortex activity.

2.0 MODEL SCALING AND ACCEPTANCE CRITERIA

2.1 Model Scaling

To obtain accurate results from a physical model study, there must be dynamic similitude between the model and the prototype. To satisfy this requirement, there must be exact geometric similitude. In addition, the ratio of the dynamic pressures must also be maintained. Strictly satisfying dynamic similitude requires a 1:1 scale model. This is usually not feasible, so some compromise is made. To accomplish this, geometric similarity is maintained and the dominant forces associated with the prototype are determined and maintained between the model and prototype.

The primary forces that affect fluid flow are viscosity, surface tension, velocity (inertial), pressure, gravity and elastic forces. In structures with a free surface, such as a pump intake, gravitational and inertial forces are far greater than the viscous and turbulent shear forces. Therefore, when modeling free surface structures, geometric similarity and the ratio of inertial to gravitational forces, or the Froude number, is maintained between the model and prototype.

Simply holding the Froude number constant violates the strict definition of dynamic similitude. However, if the model is operated within a high enough range of Reynolds numbers, viscous and surface tension scale effects may be minimized. The 2018 ANSI-9.8 Hydraulic Institute Standards recommends that the minimum Reynolds number at the pump inlet be greater than 6 x 10^4. Therefore, when choosing the model scale, it is necessary to ensure that the scaled flow rate will result in a high enough Reynolds number to minimize scale effects. It is common to be conservative and select a scale that results in a Reynolds number closer to 1 x 10^5.

Upon selecting an appropriate model or length scale, it is possible to determine relationships such as velocity, flow, and pressure between the model and prototype. This is accomplished by setting the model and prototype governing equations equal to one another. As mentioned above, the governing equation is determined by evaluating the dominating forces. These equations are typically dimensionless numbers such as the Froude, Reynolds, Weber, Euler, or Mach numbers. These common modeling relationships are shown below:

$$\text{Froude Number} \qquad F = \frac{U}{\sqrt{gL}} = \frac{\text{Inertial Force}}{\text{Gravity Force}} \qquad (2\text{-}1)$$

$$\text{Reynolds Number} \qquad Re = \frac{UL}{\nu} = \frac{\text{Inertial Force}}{\text{Viscous Force}} \qquad (2\text{-}2)$$

$$\text{Euler Number} \qquad E = \frac{\rho U^2}{\Delta P} = \frac{\text{Inertial Force}}{\text{Pressure Force}} \qquad (2\text{-}3)$$

$$\text{Weber Number} \qquad W = \frac{U}{\sqrt{\sigma/\rho L}} = \frac{\text{Inertial Force}}{\text{Surface Tension Force}} \tag{2-4}$$

$$\text{Mach Number} \qquad M = \frac{U}{\sqrt{K/\rho}} = \frac{\text{Inertial Force}}{\text{Compressive Force}} \tag{2-5}$$

Where:

U = characteristic velocity
g = gravitational constant
L = characteristic length
ρ = fluid density
ΔP = pressure difference
ν = kinematic viscosity of the fluid
σ = surface tension of the fluid
K = bulk modulus of elasticity of the fluid

If the governing equation is held constant between the model and prototype, the corresponding model flow rate, velocity, pressure, etc., can be solved directly. For example, setting the Froude number of the model equal to the prototype yields the following relationships, where the subscripts *p* & *m* denote prototype & model, respectively:

$$F_P = F_m \tag{2-6}$$

$$\frac{U_p}{\sqrt{gL_p}} = \frac{U_m}{\sqrt{gL_m}} \tag{2-7}$$

Using equation 2-7, the model velocity, and therefore, the flow rate Q can be solved for if the prototype velocity and length ratio is known. Typically, the model parameters are solved for based on the prototype to model length ratio, L_P/L_M, or L_R. Doing so yields the following equations for Q & U:

$$\frac{Q_p}{Q_m} = \mathrm{L}_\mathrm{R}^{5/2} \tag{2-8}$$

$$\frac{U_P}{U_M} = \sqrt{\mathrm{L}_\mathrm{R}} \tag{2-9}$$

Using these equations, it is possible to determine the flow rates at which the model should be operated. The Beaumont model was constructed at a 1:5.5 scale. The resulting pump inlet Reynolds number was 1.2 x 10^5 and the resulting Weber number was in excess of 1800.

2.2 Acceptance Criteria

In addition to choosing an appropriate scale with which to construct the model, it is important to evaluate the performance of the model against a set of pre-determined acceptance criteria. The criteria used for this model study closely follow and exceed those suggested in the 2018 Hydraulic Institute Standards and are as follows:

- No organized free surface or submerged vortices greater than a Type 1 (general rotation) should be permitted at Froude scaled flow rates. The HI standards suggest that a Type 3 vortex may be allowed to enter the pump if it occurs infrequently, such as less than 10-percent of the time; however, it is the goal of this study to eliminate any vortex greater than a Type 1. (note: these are based on Figure 2-1 below)

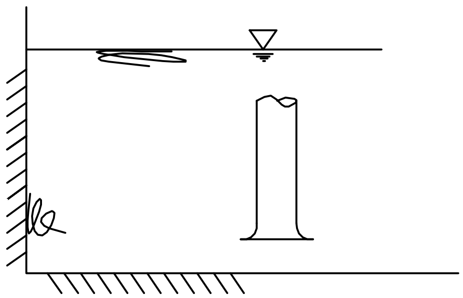
- Pre-swirl should be less than 5-degrees at the pump impeller location

- Time averaged velocities within the pump throat should not deviate more than 10 percent of the cross-sectional area average velocity.

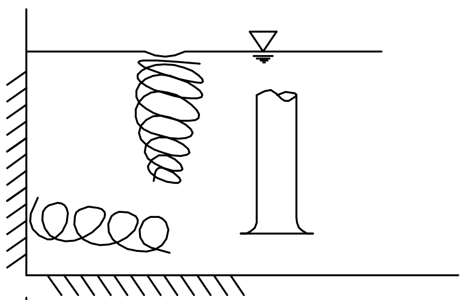
- Time-varying velocity fluctuations (turbulence) at a point within the pump throat should be less than 10 percent.

Vortex activity is evaluated qualitatively. The Hydraulic Institute Standards suggest using a scale of 1 to 6 to rank the severity of a vortex. A scale of 1 to 5 was utilized for this study, with a Type 1 being the least severe and a Type 5 being the most severe, pulling air and trash into the intake. HI varies slightly by ranking a vortex that pulls trash into the intake as a Type 5 and one that pulls air as a Type 6. However, since the acceptance criteria do not permit vortices greater than a Type 1, this variation of the HI scale does not have any effect on the outcome of the model study. Figure 2-1 presents a graphical representation of the vortex ranking used in this study.

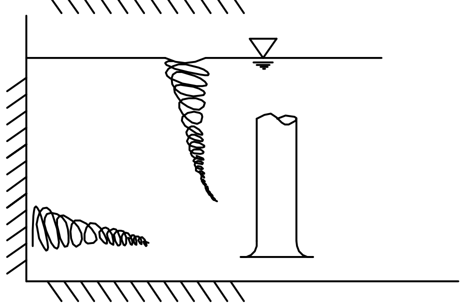
FIGURE 2-1
SURFACE & SUB-SURFACE VORTEX CLASSIFICATION



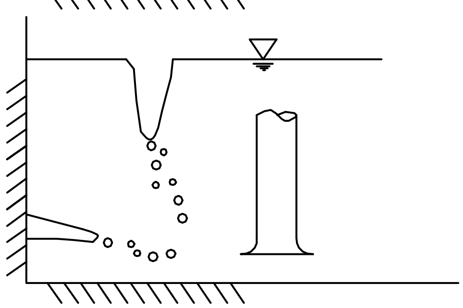
TYPE 1
SURFACE OR SUBSURFACE SWIRL



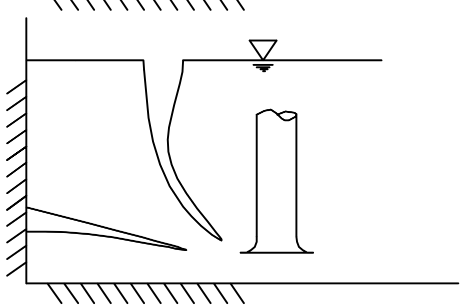
TYPE 2
SURFACE OR SUBSURFACE DIMPLE
COHERENT SWIRL



TYPE 3
ORGANIZED DYE CORE TO THE INTAKE
COHERENT SWIRL THROUGHOUT WATER
COLUMN



TYPE 4
COHERENT SWIRL AND ORGANIZED DYE CORE
PULLING BUBBLES AND SOME AIR INTO THE INTAKE



TYPE 5
COHERENT SWIRL AND SOLID AIR/VAPOR CORE PULLING DEBRIS
AND AIR INTO THE INTAKE

3.0 THE MODEL

3.1 Model Boundaries

When evaluating the portions of the pump station that are to be included in the model, it is necessary to include any components that could affect the approach flow to the pumps. This is first determined by evaluating the upstream and downstream controls. In this application, an upstream hydraulic control is a structure or component that controls the downstream flow. This may be a change in grade that results in critical flow, a sluice gate or opening that directs the flow, or simply a long stretch that results in uniform flow conditions. The Beaumont intake is fed via a single 48-in diameter influent pipe, a portion of which was included in the model and served as the upstream model boundary. The influent pipe enters a trough style baffle, with openings in the trough floor to allow flow to pass through into the wet well. After exiting the trough, flow enters an open circular wet well housing the pumps. There is a small ramp under the trough as well as a small, elevated shelf behind the pumps that the pumps sit on. No other internal features, such as vortex suppression measures or pump isolation walls are present. The trough baffle, floor openings, sloped ramp and pump support slab were included in the model. In addition, all four pumps were also included and simulated in detail.

Submersible pumps present a unique challenge in modeling because the flow typically exits the pump 90-degrees and just a short distance from the inlet. This makes it difficult to install both a roto-meter and a velocity probe at the ideal locations. Often the roto-meter is shortened significantly which makes data comparison with previous models and established acceptance criteria less reliable. CEH prefers to utilize a straight pipe which travels up through the top of the pump. The discharge piping is then simulated with “dummy pipes” and the flow is actually withdrawn vertically upward. Although this pipe does not actually exist in the field there is often a pump “rack”, some type of supports and frequently large wire for the power source that is in this region. More importantly this blockage is small relative to the pump body, is located on the opposite side as the inlet and is located in a low velocity zone. Utilizing this approach is not a simpler way to model the pump but rather it allows for a full-size roto-meter to be installed 4 diameters up from the inlet as required in the Hydraulic Institute specifications. This allows for a direct comparison with existing data and also provides adequate room to install a velocity probe and full size rotometer.

Physical model studies are used to evaluate the approach flow and ensure that the flow is uniform up to the pump impeller. Therefore, the downstream model boundary was chosen as the entrance to the pump impeller. It is not necessary to include a model pump impeller because the pump performance is tested at the manufacturer’s facility. The manufacturers test was conducted with uniform approach flow conditions. Therefore, with other design consideration being equal, if those conditions can be duplicated in the prototype structure, the performance of the pump in the field should match that determined by the manufacturer.

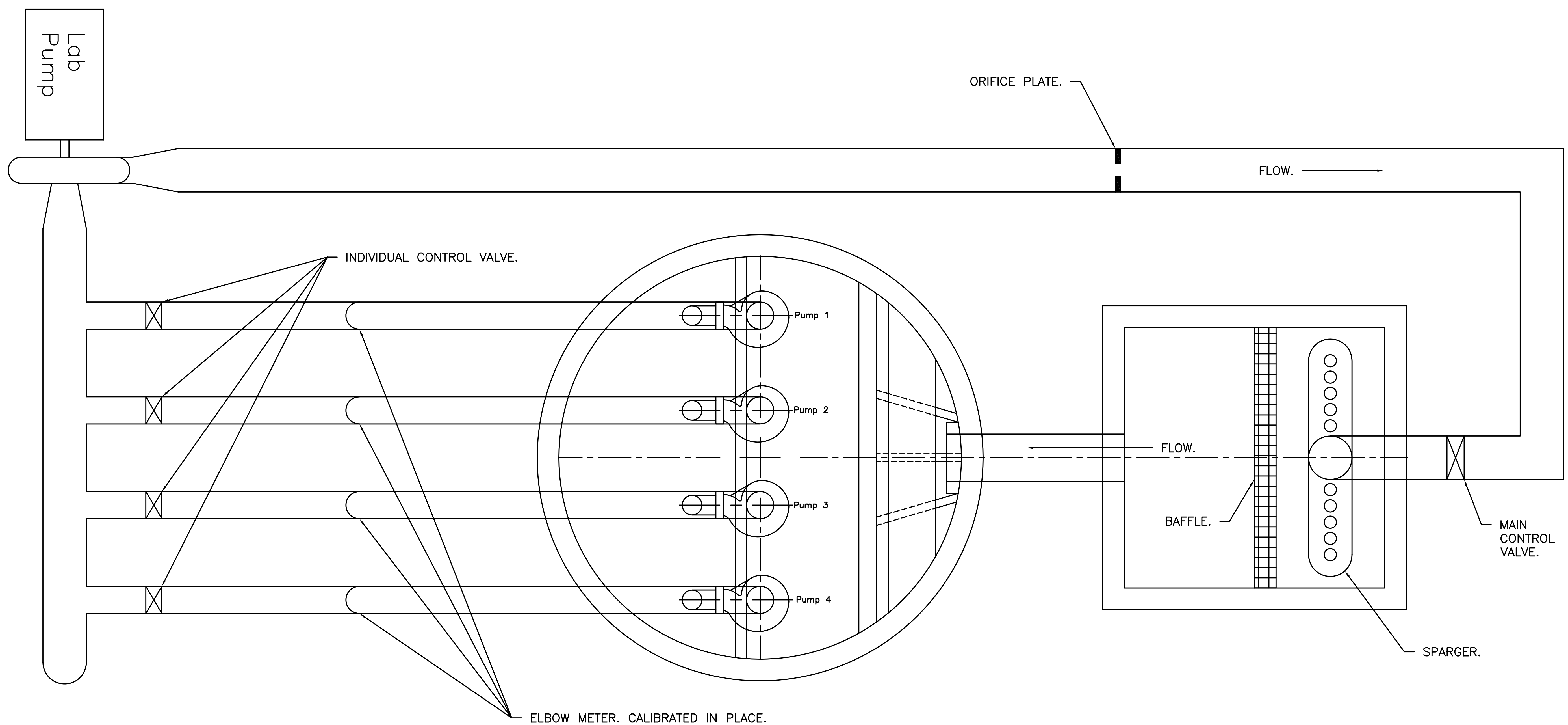
3.2 Model Construction

The model was constructed on a raised deck to facilitate viewing and data collection. The model head box, floor, and sidewalls were constructed with waterproof wood. The model pumps, intake piping and pump bells were fabricated out of clear acrylic up to the impeller location. The additional piping was fabricated out of PVC pipe. Friction losses within the model limits are negligible when compared to form or boundary losses. Therefore, it is assumed that materials mentioned above were appropriate for model construction.

The overall model basin was constructed with a tolerance of +/- 0.25 model inches. The model pump throats were constructed to within +/- 0.06 model inches. Valves were used to control the individual pump flows as well as the total model flow. A pump was installed downstream of the model pumps to re-circulate flow back to the model head box. Flow straightening devices were installed in the model head-box to ensure that flow entering the head box was uniform. Figures 3-1 through 3-4 and Photos 3-1 through 3-4 show the model.

Note:

1) All dimensions given in model inches
2) All elevations given in prototype feet
3) Basin construction tolerances ±0.25"
4) Head box construction tolerances ±0.50"
5) Acrylic intake structures construction tolerances ±0.06
6) Acrylic intake bell location tolerances ±0.13



Model Scale: 1 model inch =5.5 prototype inches (1:5.5)

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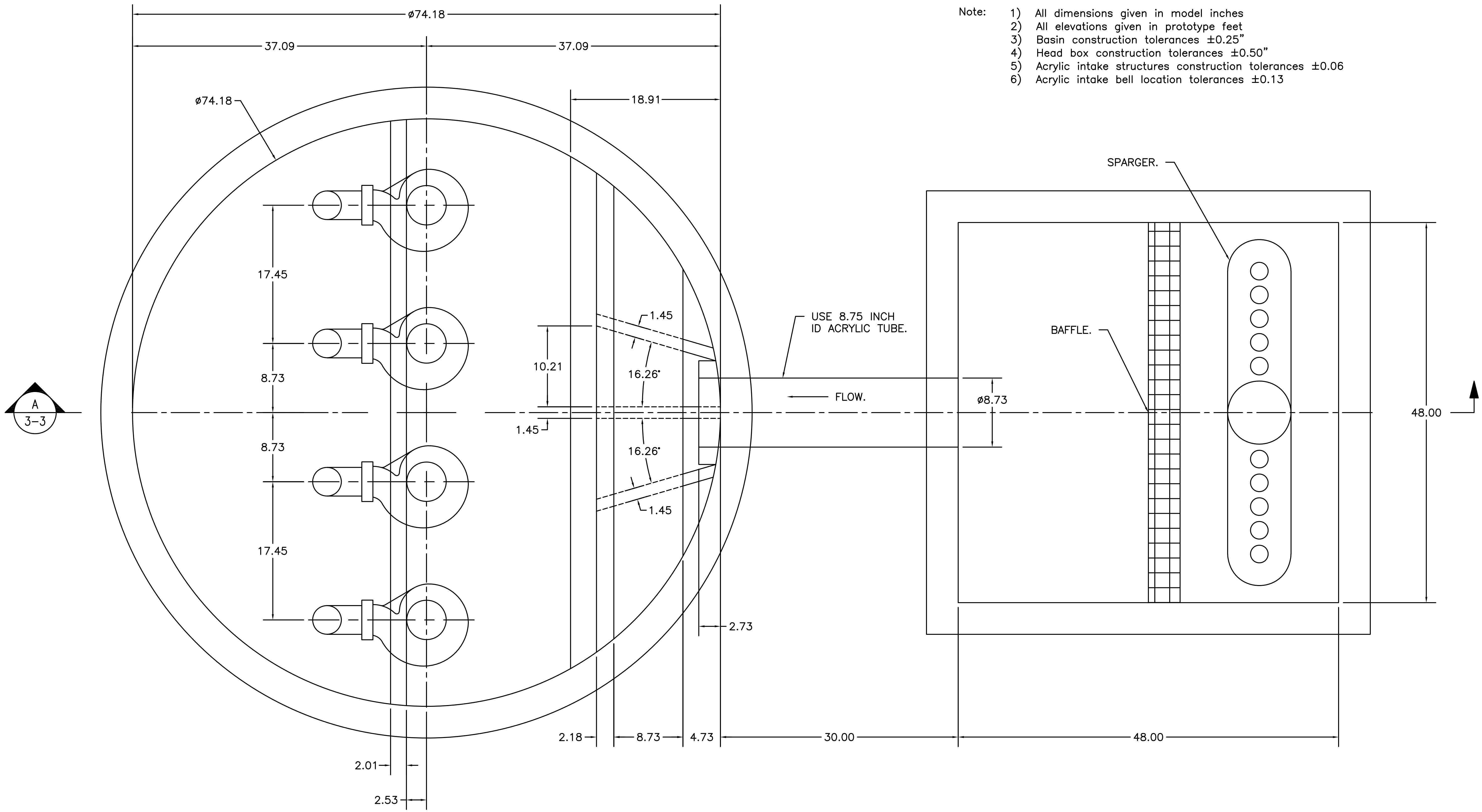
DRAWING SCALE:	DRAWN: K. Davy	DATE: 11/8/2021	PROJECT NO:
1:12	FILE NO: OVERVIEW	CHECKED:	

FIGURE 3-1
MODEL OVERVIEW
BEAUMONT
FREESE AND NICHOLS



Note:
1) All dimensions given in model inches
2) All elevations given in prototype feet
3) Basin construction tolerances ±0.25"
4) Head box construction tolerances ±0.50"
5) Acrylic intake structures construction tolerances ±0.06
6) Acrylic intake bell location tolerances ±0.13

Model Scale: 1 model inch =5.5 prototype inches (1:5.5)

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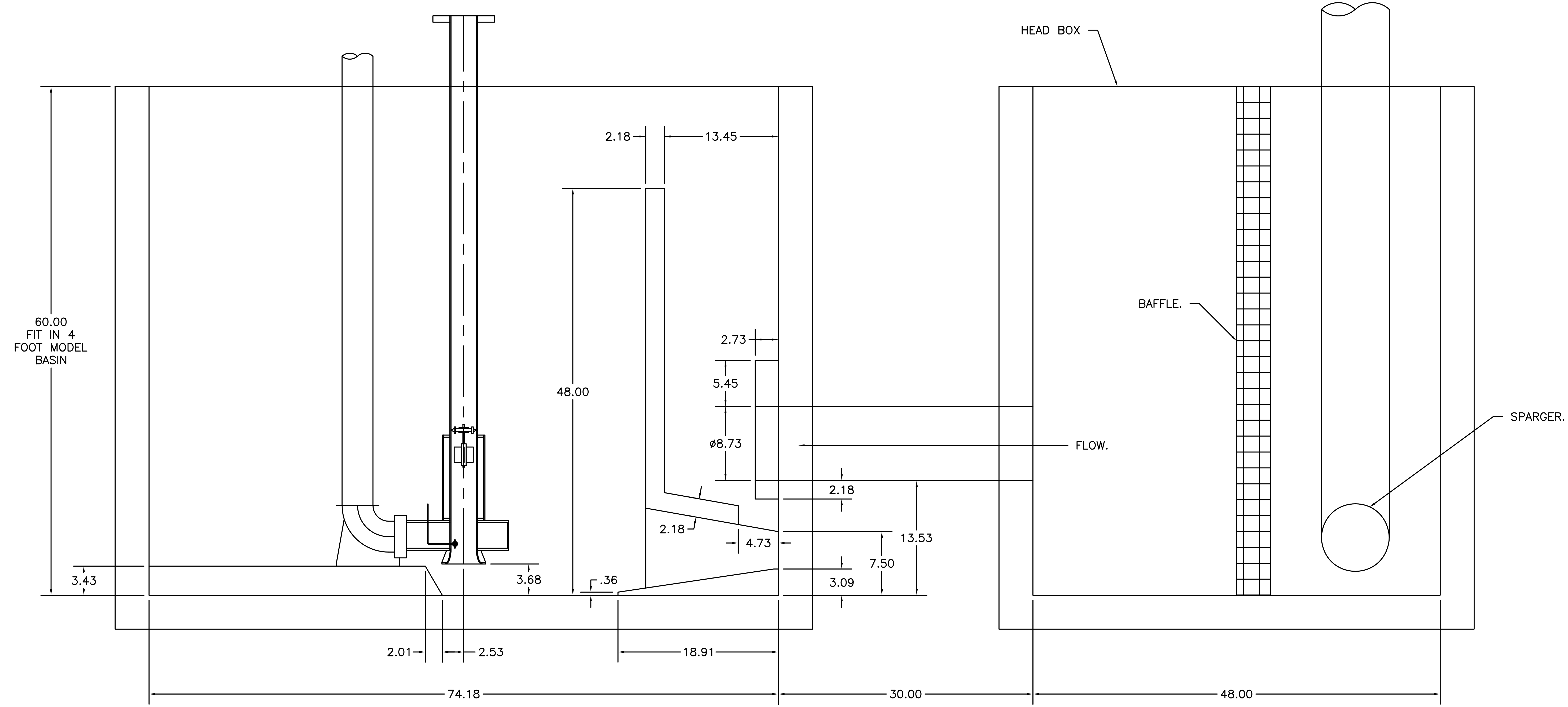
DRAWING SCALE:	DRAWN: K. Davy	DATE: 11/8/2021	PROJECT NO:
1:12	FILE NO: Plan	CHECKED:	

FIGURE 3–2
MODEL LAYOUT DETAILS
BEAUMONT
FREESE AND NICHOLS

Note:

1) All dimensions given in model inches
2) All elevations given in prototype feet
3) Basin construction tolerances ±0.25"
4) Head box construction tolerances ±0.50"
5) Acrylic intake structures construction tolerances ±0.06
6) Acrylic intake bell location tolerances ±0.13



Model Scale: 1 model inch =5.5 prototype inches (1:5.5)

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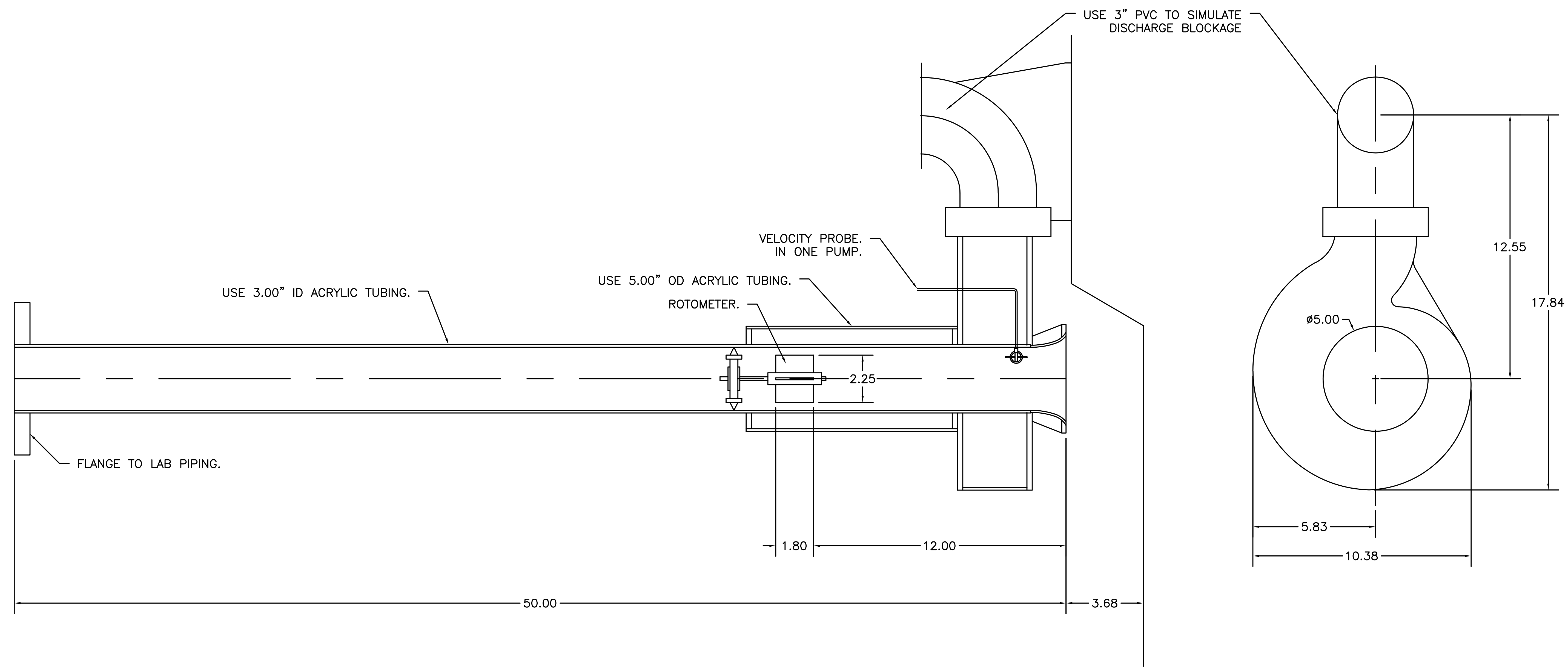
DRAWING SCALE:	DRAWN: K. Davy	DATE: 11/8/2021	PROJECT NO:
1:12	FILE NO: SECTION A	CHECKED:	

FIGURE 3-3
MODEL SECTION A DETAILS
BEAUMONT
FREESE AND NICHOLS

Note:
1) All dimensions given in model inches
2) All elevations given in prototype feet
3) Basin construction tolerances ±0.25"
4) Head box construction tolerances ±0.50"
5) Acrylic intake structures construction tolerances ±0.06
6) Acrylic intake bell location tolerances ±0.13



Model Scale: 1 model inch =5.5 prototype inches (1:5.5)

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DRAWN: K. Davy	DATE: 11/8/2021	PROJECT NO:	
FILE NO: PUMP	CHECKED:		

FIGURE 3-4
SIMPLIFIED MODEL PUMP DETAILS
BEAUMONT
FREESE AND NICHOLS

Photo 3-1 Model Overview

Photo 3-2 Trough Baffle

Photo 3-3 Wet Well

Photo 3-4 Model Pump

4.0 INSTRUMENTATION AND TESTING PROCEDURES

4.1 Instrumentation and Data Collection

The individual model pump flow rates, as well as the total model flow rate were determined with an ASME standard orifice meter with an accuracy of +/- 2 percent or better. U-tube manometers as well as a Dwyer Series 475 differential manometer were used to measure the manometer deflection. Valves were adjusted in the model piping until the manometer deflections indicated that the proper flow rates were set.

The water levels in the pump sump were recorded with a staff gauge referenced to the sump floor with an accuracy of 3-mm (0.01-ft) or better). Vortex formation was visually observed. Dye was used to aid in the visualization of vortex formation. Vortex strength was rated according to the scale presented in Figure 2-1. Digital photographs and video footage were also used to document vortex formation.

Velocity fluctuations and turbulence levels were measured just upstream of the pump bell. A free spinning miniature propeller Model 412 Nixon Streamflow probe was used to measure the velocities. A data acquisition board was connected to the Nixon probe and recorded approximately 9000 samples over a 30-second period. The software program HPVEE was used to record this data and determine the mean and standard deviation of the velocity data. The pump bell was attached to a turn-column, which allowed the velocity probe to be rotated 360 degrees. Velocities were collected at 8 points around the pump bell, at a fixed radius, in 45-degree increments.

A swirl meter was installed in each detailed pump to measure the level of pre-swirl of flow entering the pump. Each swirl meter consists of 4 straight vanes mounted on a shaft. The swirl angle can be calculated with the following equation:

$$\theta = \tan^{-1}\left(\frac{\pi \mathrm{dn}}{\mathrm{u}}\right)$$

Where: u = average axial velocity
d = diameter of the pipe in which the swirl meter is installed
n = revolutions per second of the swirl meter

4.2 Test Program

Testing is conducted in three phases, baseline, modification, and final documentation testing. Each of these phases is described below:

- Baseline Testing: Tests were conducted with the proposed intake structure. These tests were conducted to evaluate the approach flow conditions, and to determine if any adverse hydraulic phenomena were present. In general, vortex activity, pre-swirl, velocity distribution, turbulence levels, and overall approach flow conditions were evaluated.

- Modification Testing: Tests were conducted to develop modifications that would alleviate or minimize any potentially damaging hydraulic conditions within the sump. These tests were conducted systematically to minimize design changes while still meeting the pre-determined acceptance criteria.

- Final Documentation Testing: Following witness testing (if any), documentation testing is conducted, if needed, to verify that the recommended modifications are effective for a range of expected operating conditions.

5.0 TEST RESULTS

5.1 Baseline Testing

Baseline tests were conducted for the station with several possible operating conditions. These tests were conducted at low and high-water levels. In general, the following observations were made:

1. Initial testing showed that overall conditions in the trough baffle and in the wet well were turbulent and unstable. With no flow over the top of the vertical trough wall, all flow had to pass through the floor openings, which resulted in accelerated, high velocity flow on the floor approaching the pumps.
2. The high velocity approach flow on the floor passed under the pumps and lifted vertically upward once onto the pump support slab. This phenomenon was observed for all operating conditions (1-3 pumps in operation).
3. Stable, well developed floor vortex activity was observed under the pumps. Intermittent back wall vortices were also observed forming behind the pumps.
4. Overall pre-swirl values were elevated and unstable, with frequent stalling and burst swirl observed.

A summary of the baseline testing is shown in Table 5-1.

Table 5-1 Baseline Data Summary

Note: Pump 1 on the left side looking upstream (toward the inlet); Pump 4 was on the right (see Figure 3-1 for pump orientation). Pump 1 was instrumented with a velocity probe. All pumps were instrumented with rotometers. Velocity fluctuations should be less than 10%, pre-swirl should be less than 5.0-degrees, and no vortices greater than type 1 or weak type 2 should enter the pump.

The velocity probe malfunctioned during baseline testing; therefore, no velocity data is presented.

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 1	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	I 2-3	none	C 3	none				11.4
Pump 2	15	none	I 2-3	none	C 3	none	No probe installed			9.2
Pump 3	15	none	I 2-3	none	C 3	none	No probe installed			7.4
Pump 4	0									
Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft. Overall conditions are turbulent and unstable Accelerated, high velocity flow observed on the floor Flow on the floor passes under the pumps and travels vertically upward behind pumps Strong floor vortex activity observed under all pumps Intermittent backwall vortices were also observed entering the pumps Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed										

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 2	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	I 2-3	none	C 3	none				12.5
Pump 2	0									
Pump 3	15	none	I 2-3	none	C 3	none	No probe installed			6.8
Pump 4	15	none	I 2-3	none	C 3	none	No probe installed			12.1
Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft. Overall conditions are turbulent and unstable Accelerated, high velocity flow observed on the floor Flow on the floor passes under the pumps and travels vertically upward behind pumps Strong floor vortex activity observed under all pumps Intermittent backwall vortices were also observed entering the pumps Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed										

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 3	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	I 2-3	none	C 3	none				9.8
Pump 2	15	none	I 2-3	none	C 3	none	No probe installed			8.5
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Overall conditions are turbulent and unstable
Accelerated, high velocity flow still observed on the floor
Flow on the floor passes under the pumps and travels vertically upward behind pumps
Vortex activity is unchanged
Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 4	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	15	none	I 2-3	none	C 3	none	No probe installed			9.2
Pump 3	0									
Pump 4	15	none	I 2-3	none	C 3	none	No probe installed			12.5

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Overall conditions are turbulent and unstable
Accelerated, high velocity flow still observed on the floor
Flow on the floor passes under the pumps and travels vertically upward behind pumps
Vortex activity is unchanged
Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 5	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	19.5	none	I 2-3	none	C 3	none				7.9
Pump 2	0									
Pump 3	0									
Pump 4	0									
Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft. Overall conditions are turbulent and unstable Accelerated, high velocity flow still observed on the floor Flow on the floor passes under the pumps and travels vertically upward behind pumps Vortex activity is unchanged Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed										

Base Line	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 6	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	19.5	none	I 2-3	none	C 3	none				4.8
Pump 3	0									
Pump 4	0									
Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft. Overall conditions are turbulent and unstable Accelerated, high velocity flow still observed on the floor Flow on the floor passes under the pumps and travels vertically upward behind pumps Vortex activity is unchanged Pre-swirl is elevated and unstable – frequent stalling and burst swirl observed										

The following pictures show some of the conditions observed in the wet well. Photography is difficult with this wet well configuration due to the pump geometry and the back-wall pump support but video is being provided which will allow easier observation of conditions. Video footage of the testing will show conditions more clearly.

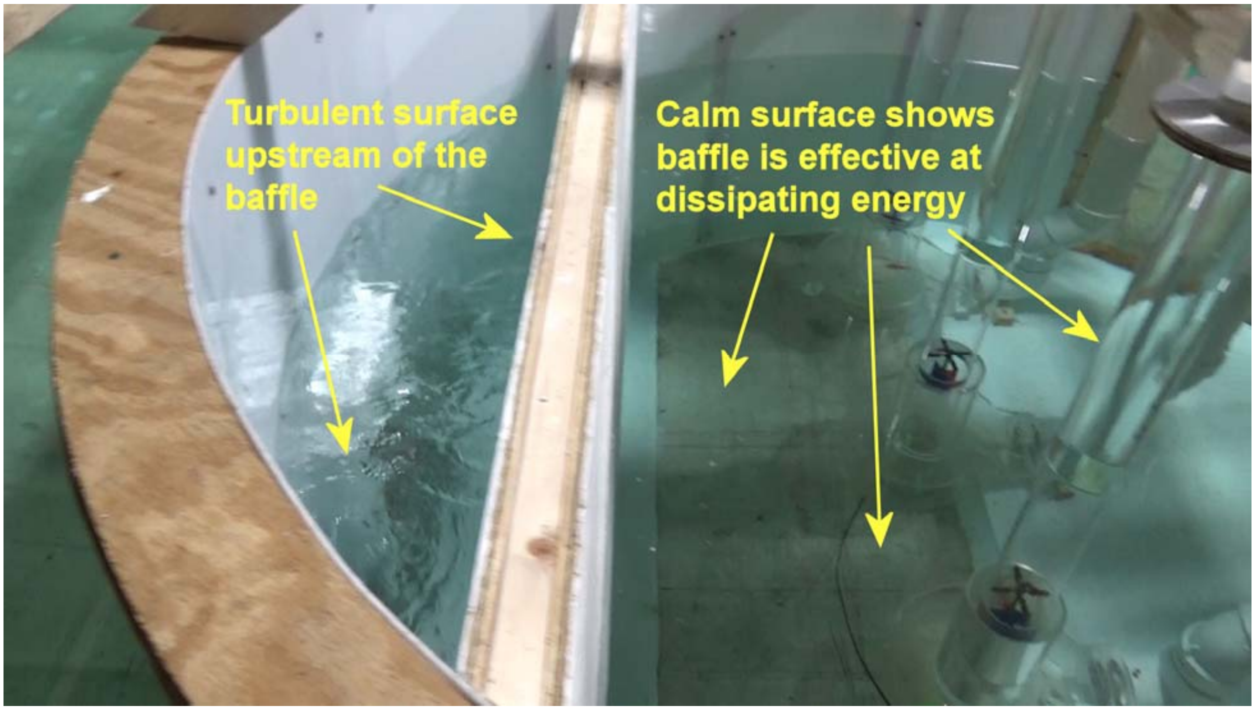


Photo 5-1 Calm Surface in Wet Well

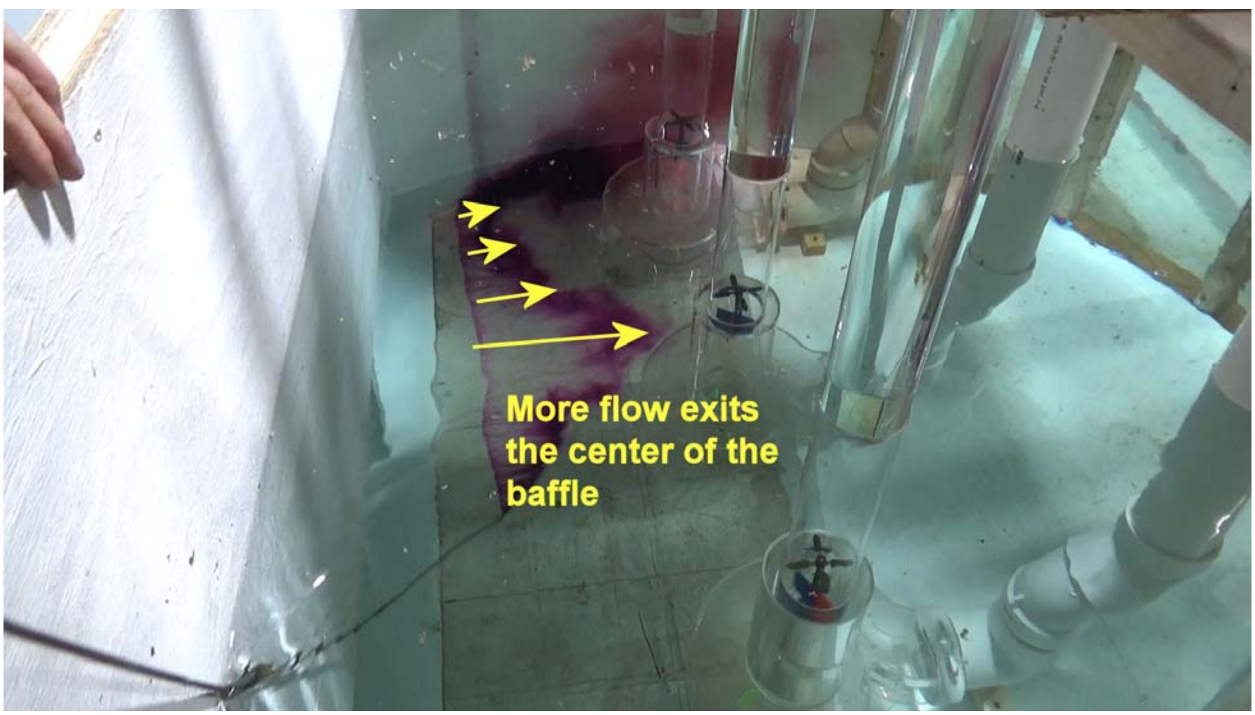


Photo 5-2 Non-Uniform Flow Approaching The Pumps

Photo 5-3 High Velocity Flow on Wet Well Floor

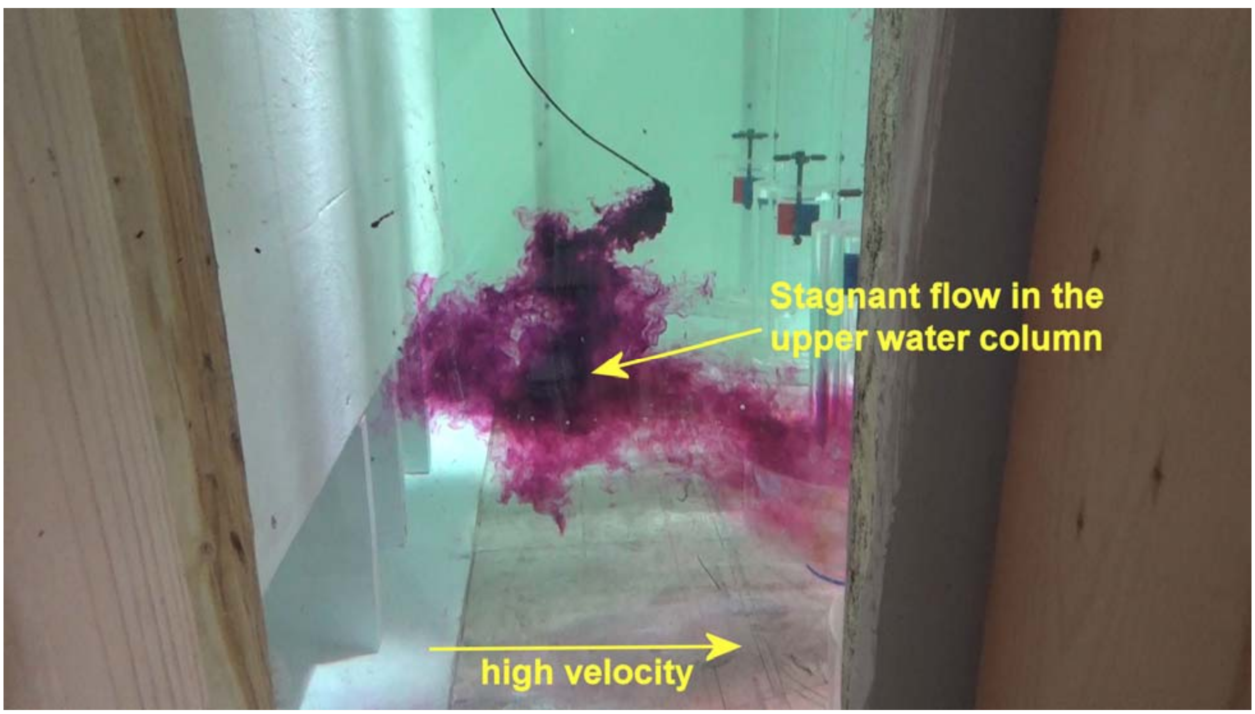


Photo 5-4 Stagnant Mid-Column Flow

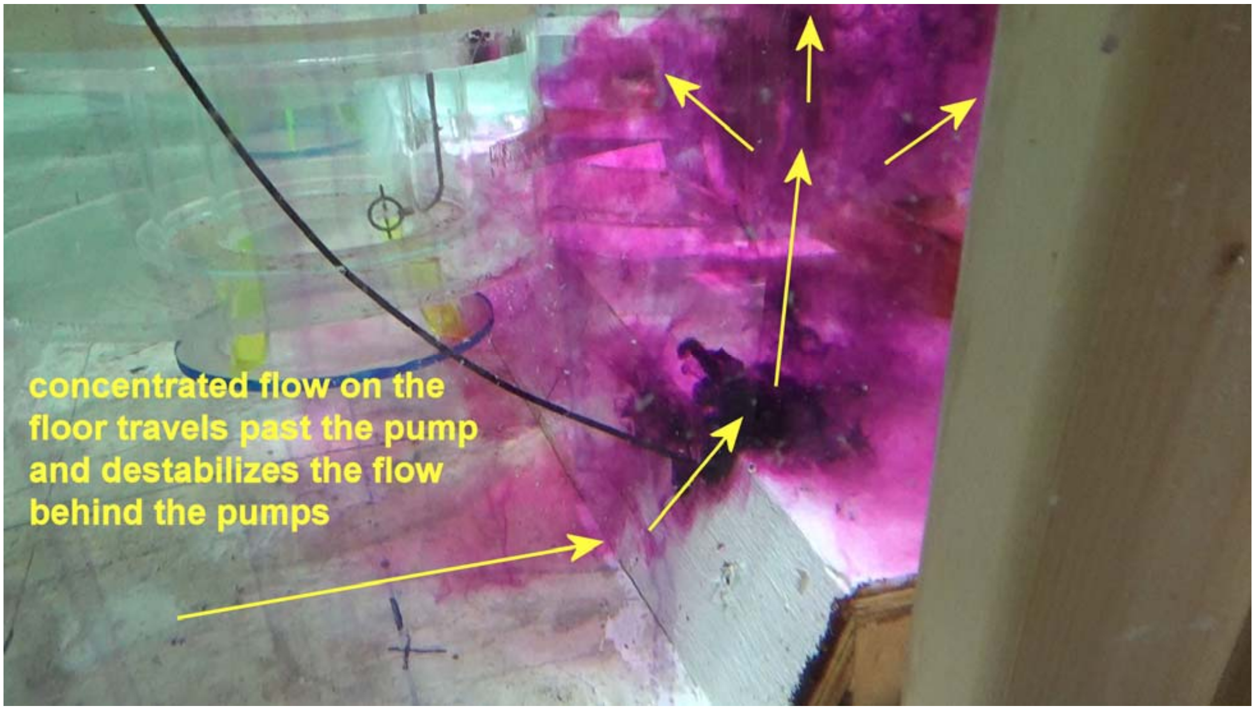


Photo 5-5 Turbulent Flow Behind Pumps

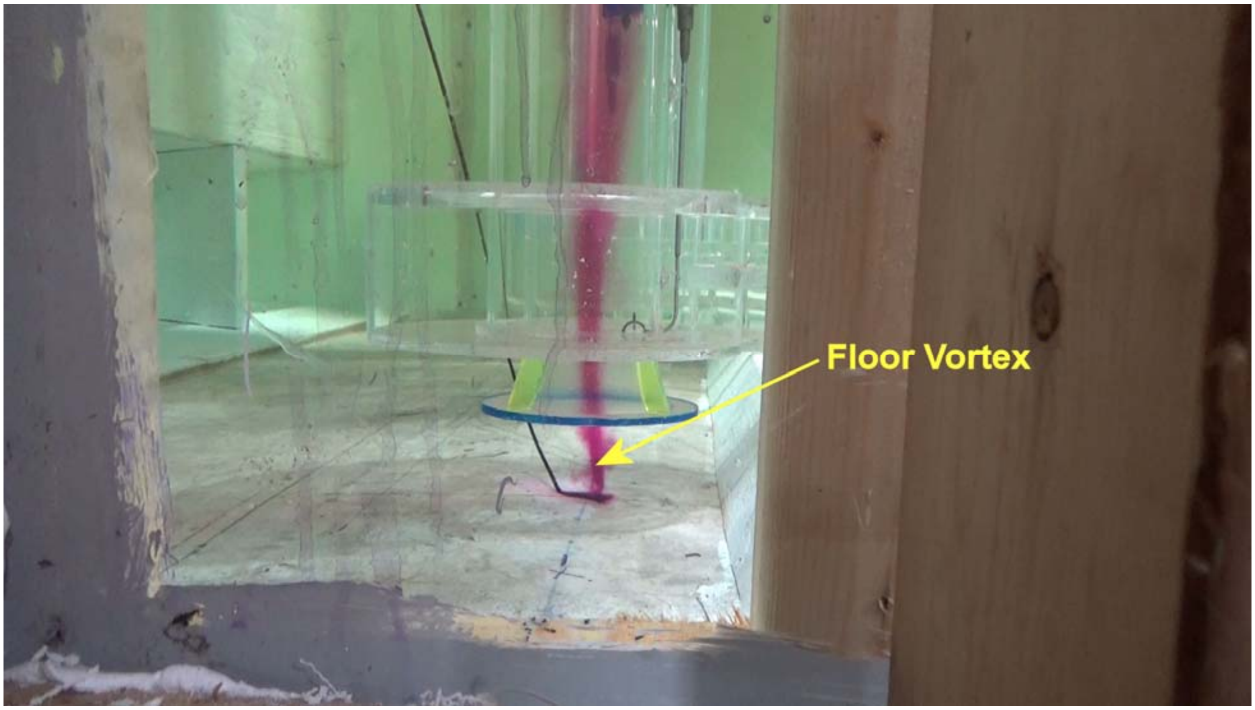


Photo 5-6 Floor Vortex

5.2 Modification Testing

Modification tests were conducted to improve the approach flow conditions within the pump sump. Complete data sets may not be taken during each test and all conditions are not investigated during this phase of testing. In general:

1. Baseline testing indicated that submerged vortex activity and accelerated flow on the wet well floor were the two main hydraulic issues that required mitigation.
2. In order to reduce the approach velocity on the floor of the wet well, the vertical trough wall was revised by removing sections on each side of the wall. The center portion of wall remained unchanged. The openings on the side of the wall allowed water to pass through, thus reducing the velocity through the floor openings and the velocity on the wet well floor approaching the pumps.
3. Floor cones were installed under the pumps and were effective at preventing floor vortex activity. With the overall approach flow improved, intermittent mid flow and sidewall vortices were observed; therefore, dividing floor splitters were installed in between the pumps and sidewall fillets were installed on the curved outer wet well walls adjacent to the outer pumps. The fillets and splitters were effective at preventing both sidewall and mid flow vortex activity
4. With the modifications installed, approach velocities on the wet well floor were significantly reduced and vortex activity was minimized.

Table 5-2 summarizes the modification testing.

Table 5-2 Summary of Modification Tests

Mod	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 1	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	I 2-3	I 2-3	none	I 2-3	-4.5	6.9	18.9	0.9
Pump 2	15	none	I 2-3	none	none	I 2-3	No probe installed			1.1
Pump 3	15	none	I 2-3	none	none	I 2-3	No probe installed			1.2
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Vertical trough wall height revised – top lowered so water can pass over the top
Floor cones installed under all pumps
Too much flow passes over the top of the wall – no flow through the center portion of the trough floor
Upstream flow observed on the floor and under the pumps
Floor cones prevent floor vortex activity – sidewall, backwall and mid flow vortices still observed
Pre-swirl is lower but is still unstable

Mod	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 2	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	I 2-3	none	I 2-3	-6.4	6.2	13.9	0.8
Pump 2	15	none	none	none	none	I 2-3	No probe installed			0.9
Pump 3	15	none	none	none	none	I 2-3	No probe installed			1.6
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Flow on the wet well floor all downstream and stable
Improved approach flow reduces minimizes backwall vortex activity
Floor cones prevent floor vortex activity – sidewall and mid flow vortices still observed
Pre-swirl is low and stable

Once the velocity was reduced and stabilized around the pump, well developed mid-flow vortices formed between pumps as shown on the following photo.

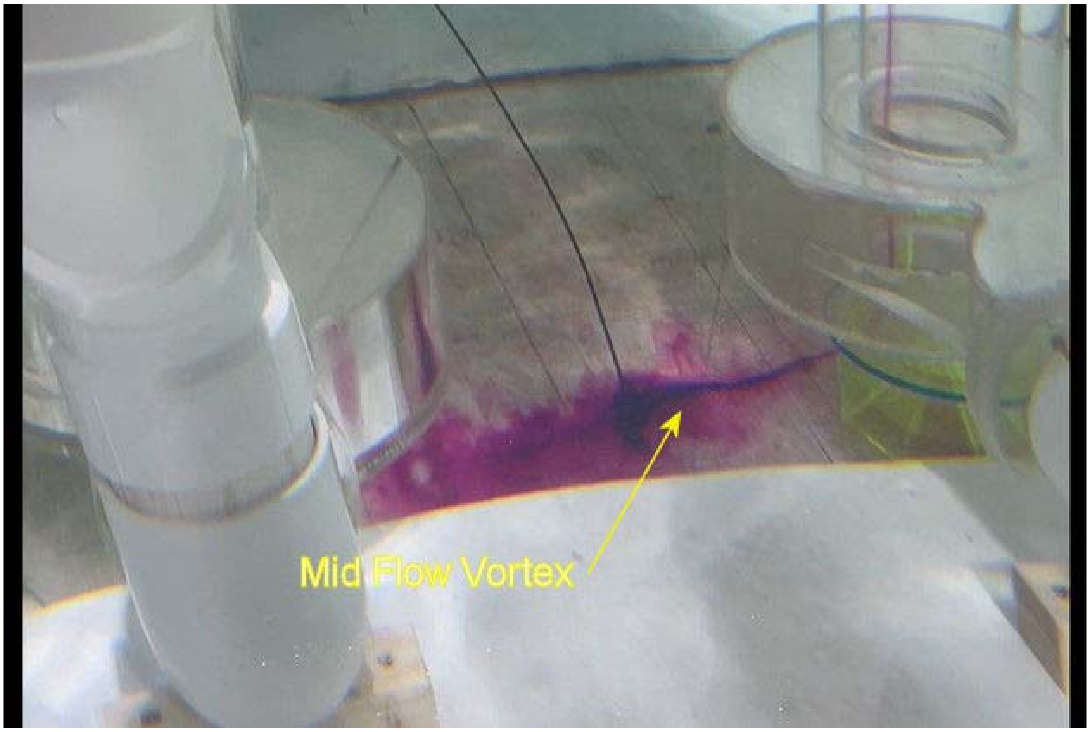


Photo 5-7 Mid Flow Vortex (without dividing splitters installed)

Mod	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 3	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-4.7	3.1	7.0	1.6
Pump 2	15	none	none	none	none	none	No probe installed			0.6
Pump 3	15	none	none	none	none	none	No probe installed			1.0
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall further revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Note: All remaining data is presented in the final documentation section. The following Photos and Figures show the recommended modifications in place.

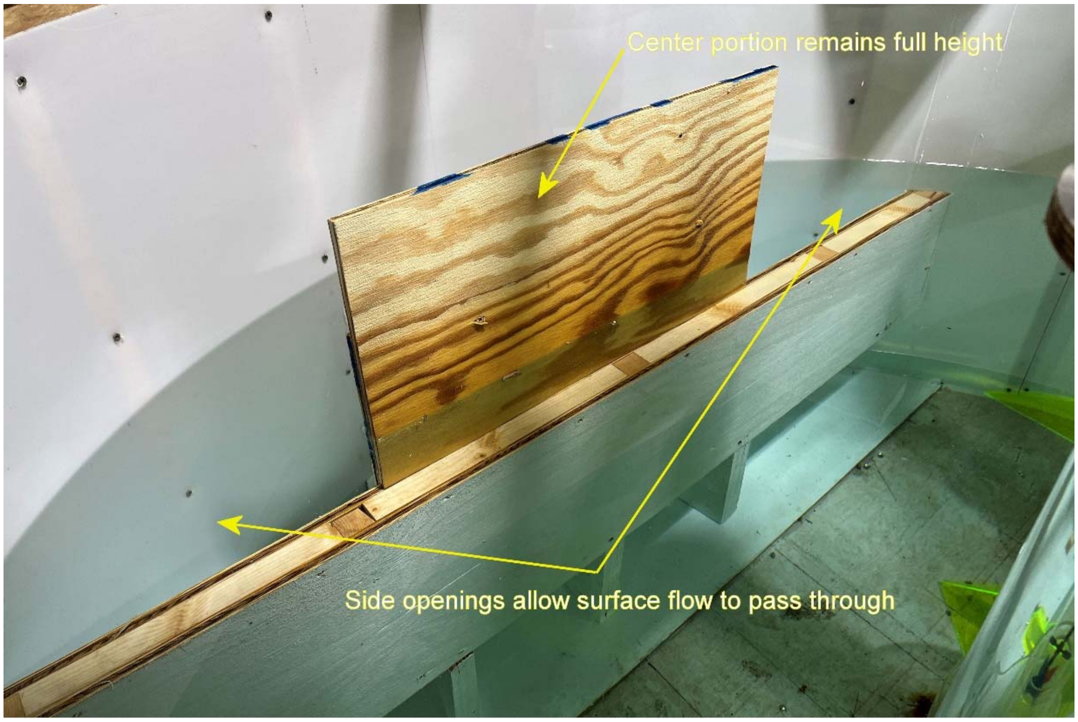


Photo 5-8 Revised Trough Wall

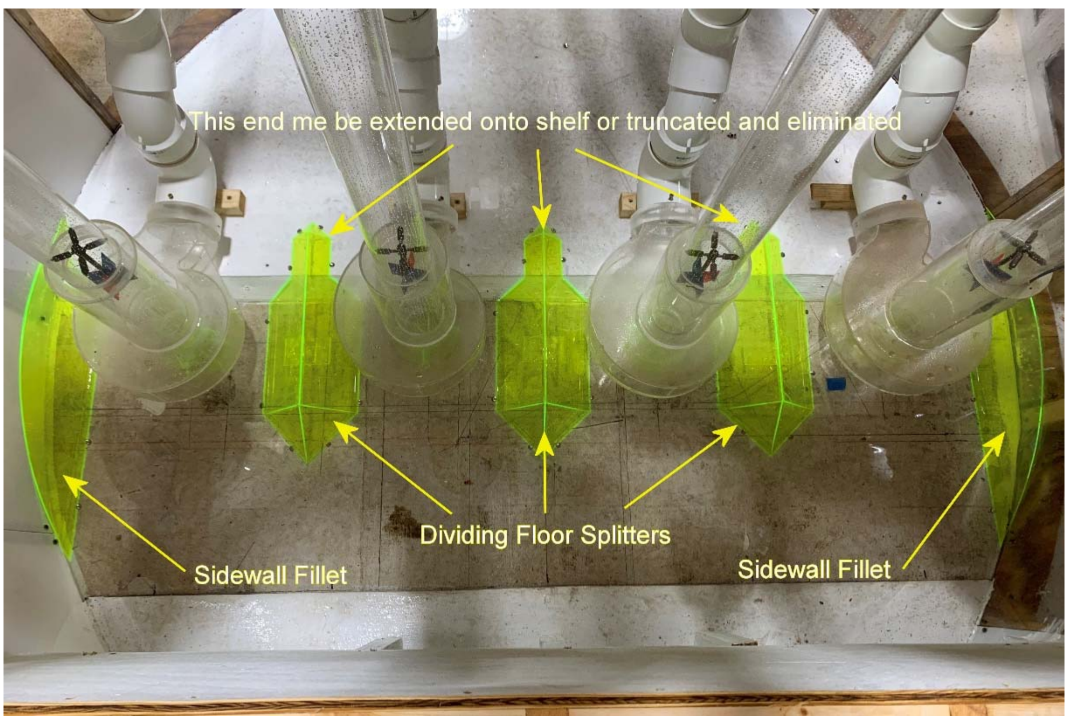


Photo 5-9 Sidewall Fillets / Dividing Floor Splitters

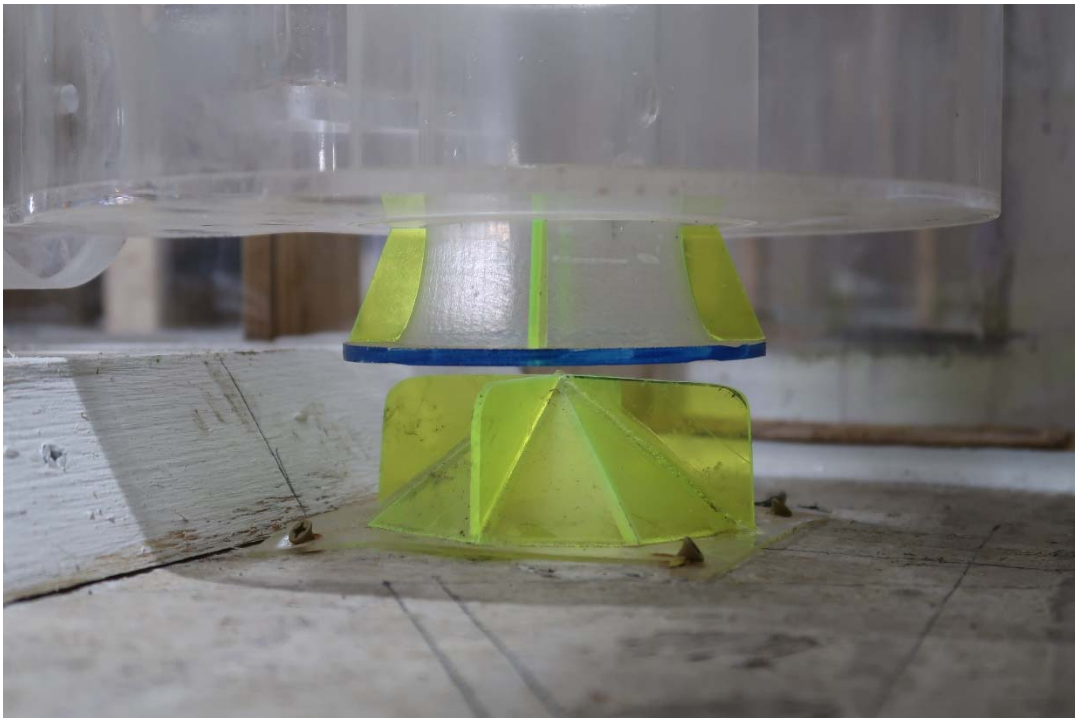
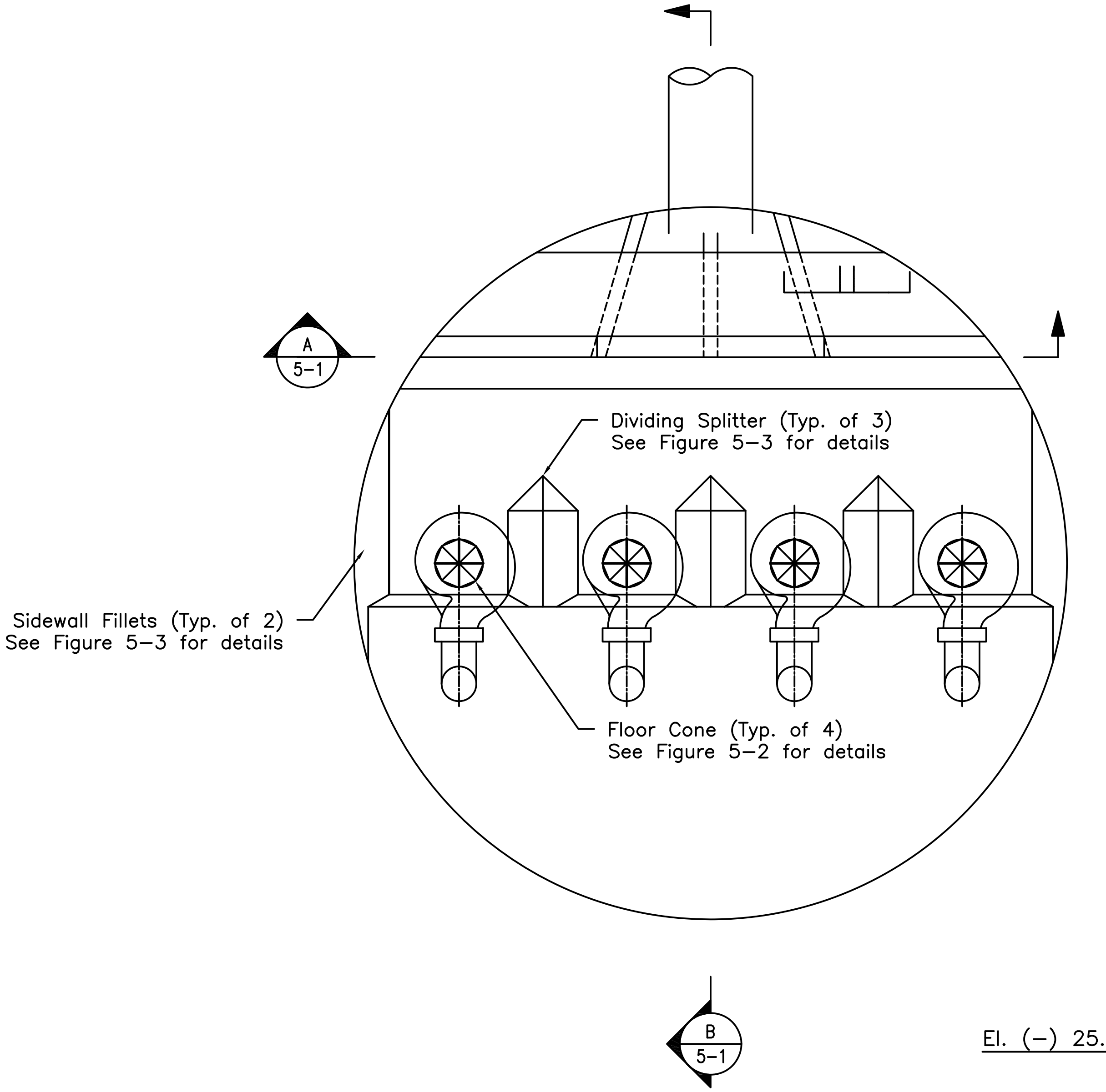
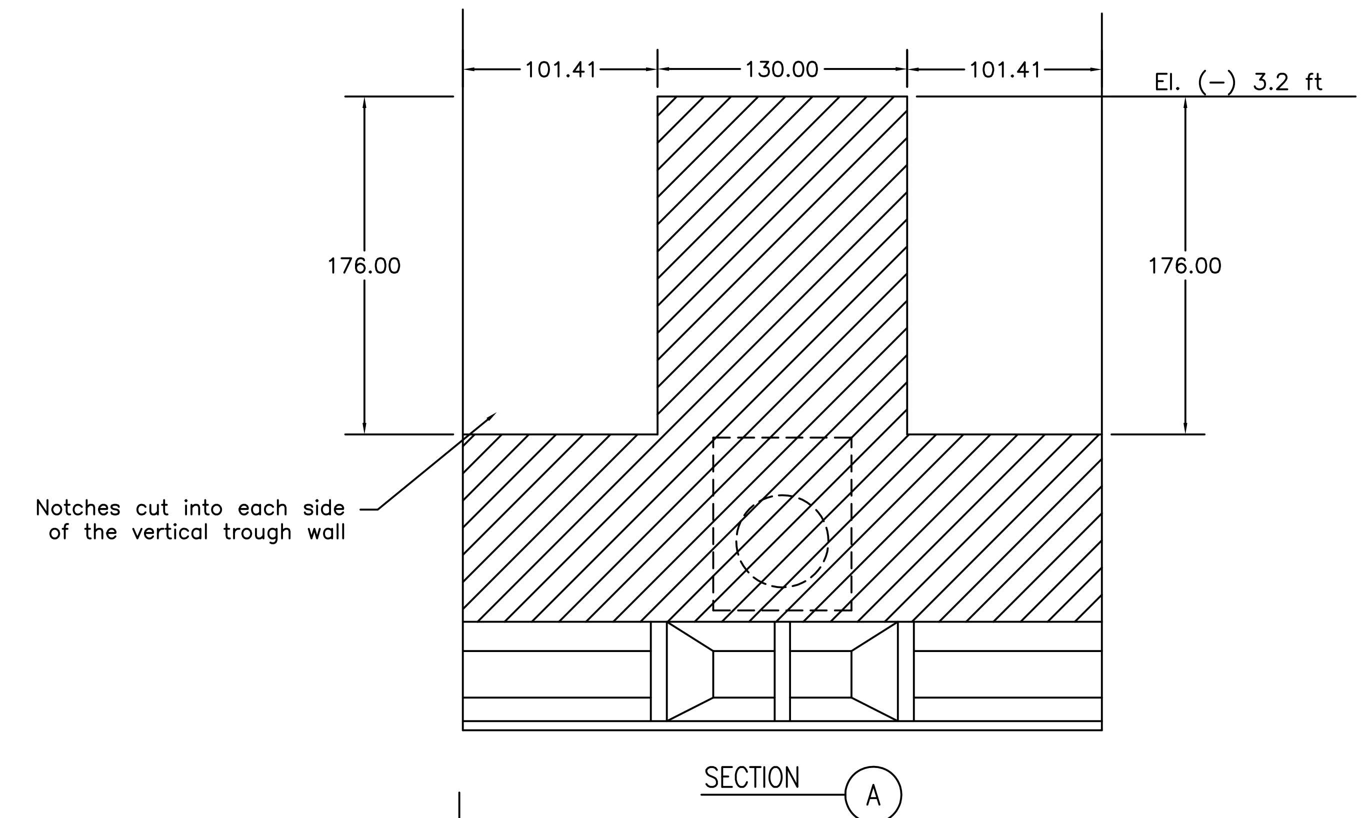


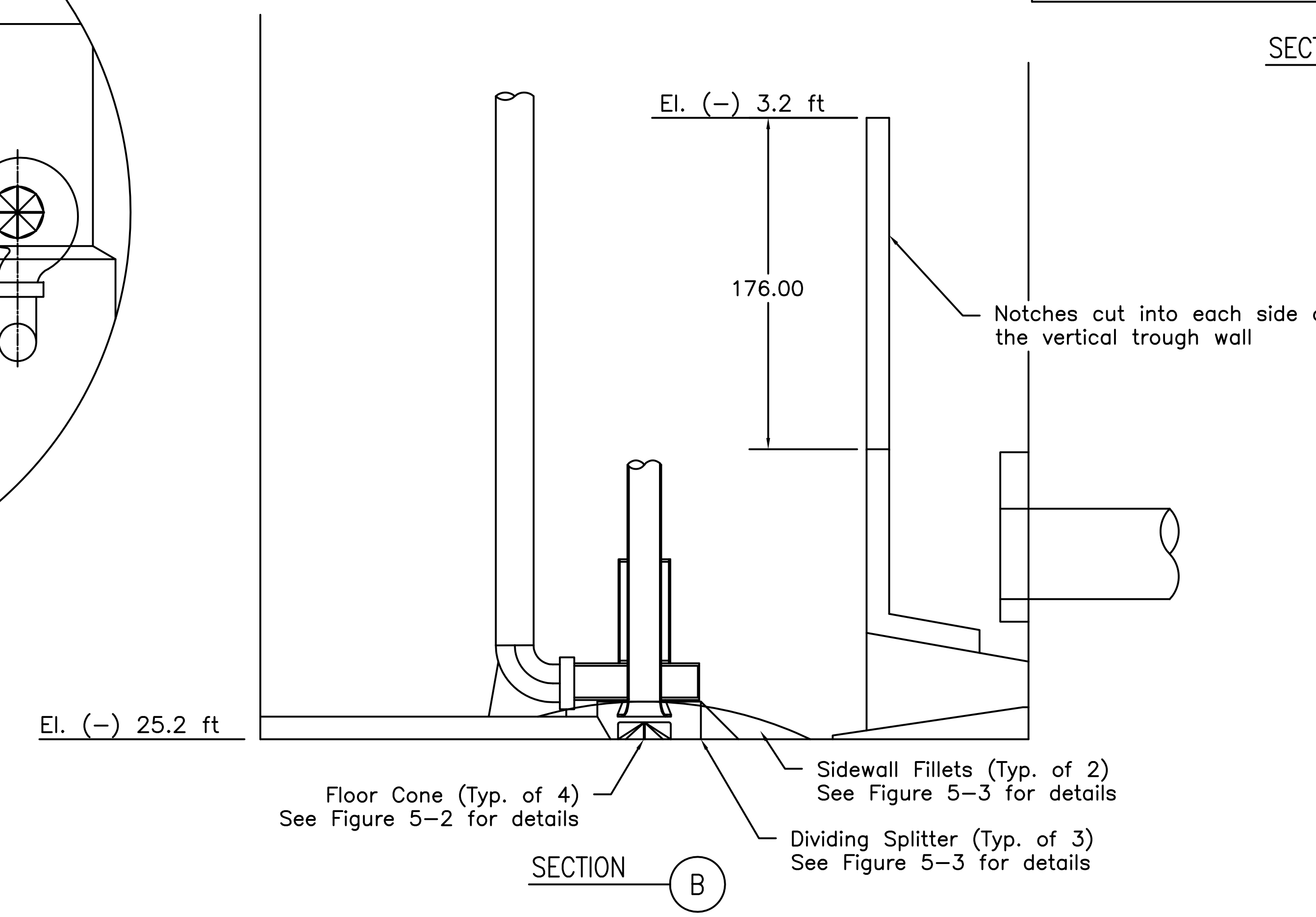
Photo 5-10 Floor Cone

The following modifications are recommended:

1. The vertical trough baffle wall should be revised by notching the sides to allow flow over the outer portions of the wall.
2. Sidewall fillets and dividing splitters should be installed in between the pumps and on the outer wall adjacent to the outer pumps.
3. Floor cones should be installed under each pump.







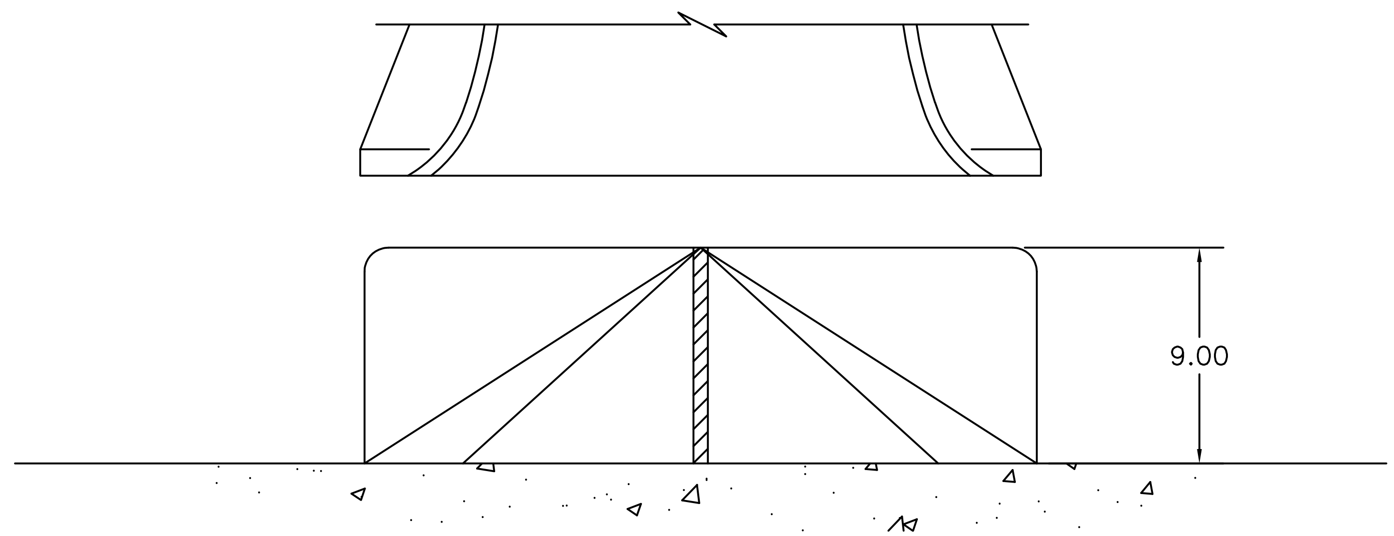
Note: Drawing intended for reference only. Not to be used as a construction drawing.

Note: 1) All dimensions given in prototype inches.
2) All elevations given in prototype feet.

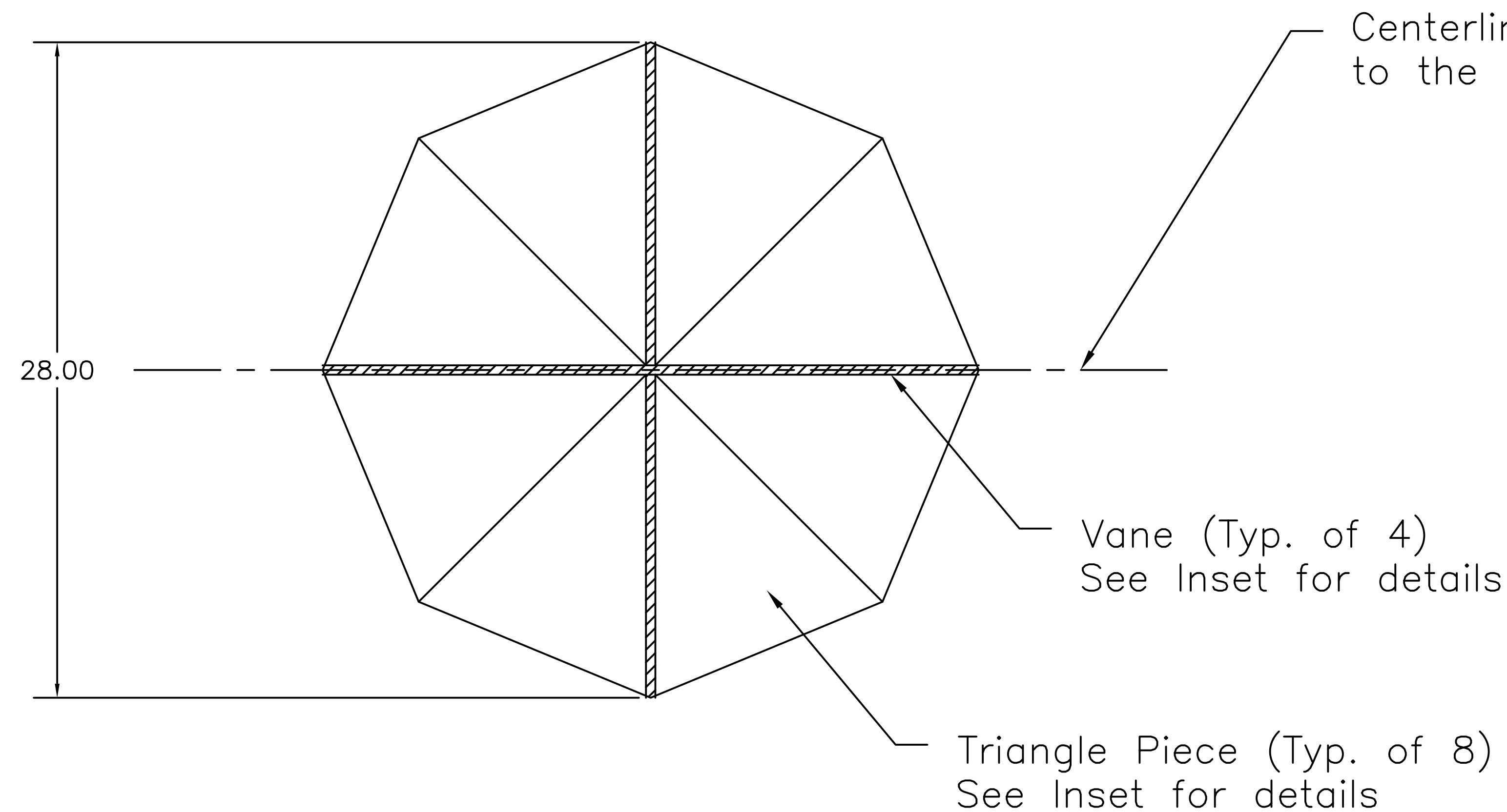
NO.	DATE:	REVISION	DRAWN:	CHK. BY:

DRAWING SCALE:	DRAWN: M. Havice	DATE: 11/24/2021	PROJECT NO:
1:100	FILE NO: Plan	CHECKED:	

FIGURE 5–1
MODIFICATION DETAILS – OVERVIEW
BEAUMONT
FREESE AND NICHOLS

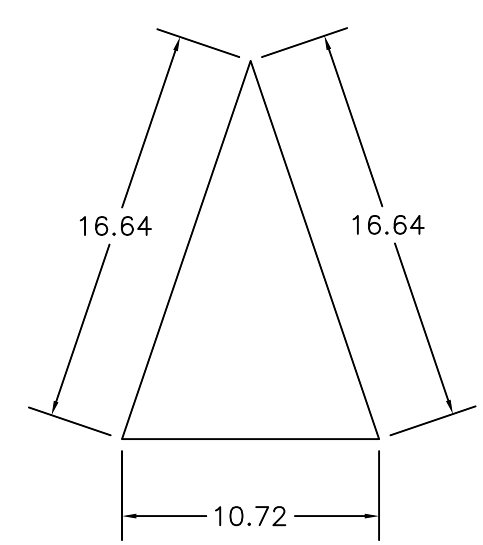


Notes:
1. All dimensions given in prototype inches
2. Cone Specifications:
   Fabricated out of 8 triangle pieces (see detail)
   Total Height = 9.0 in.
   Base Diameter = 28.0 in.
3. Fabrication and attachment design by others

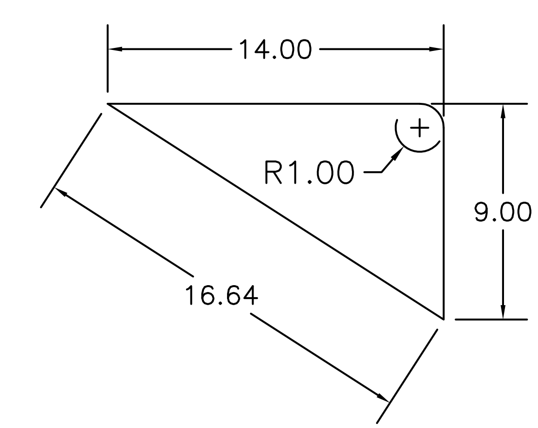


Top View

Triangle Details



Vane Details



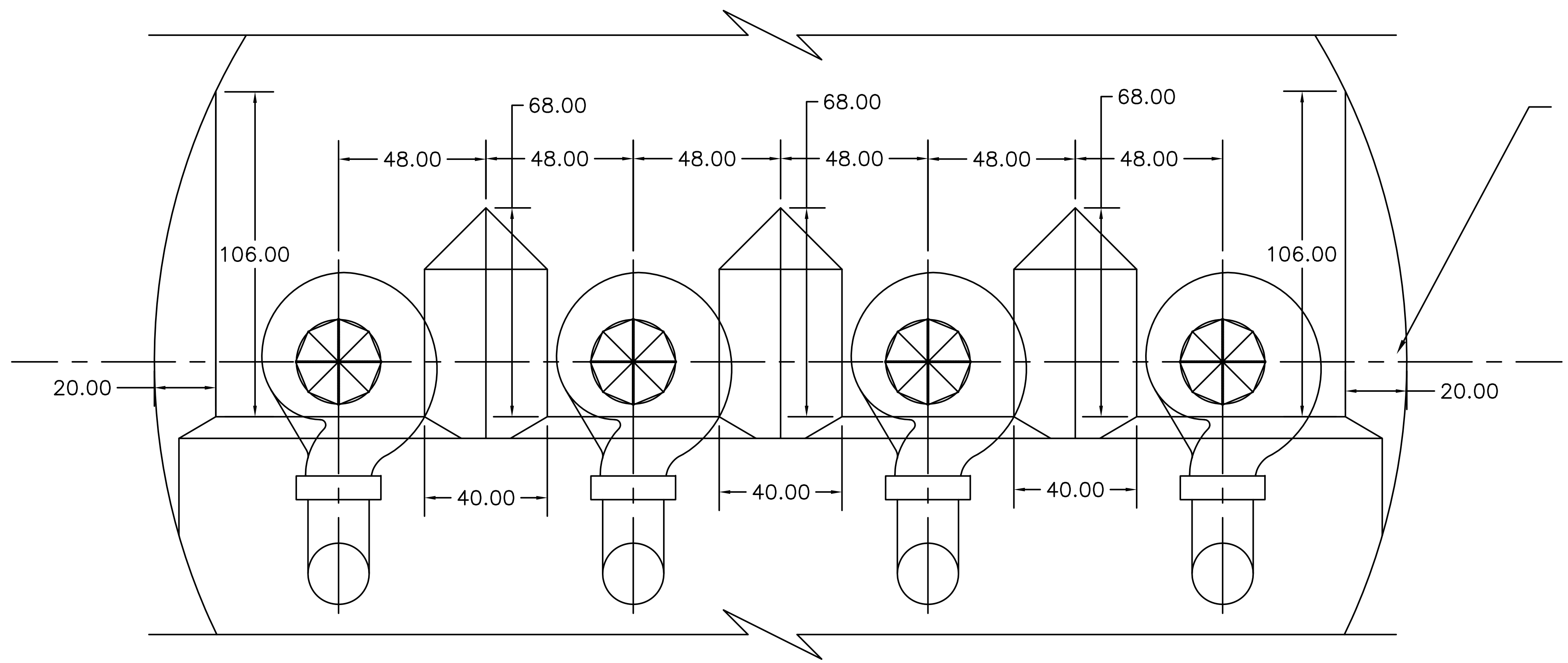
Note: Drawing intended for reference only. Not to be used as a construction drawing.

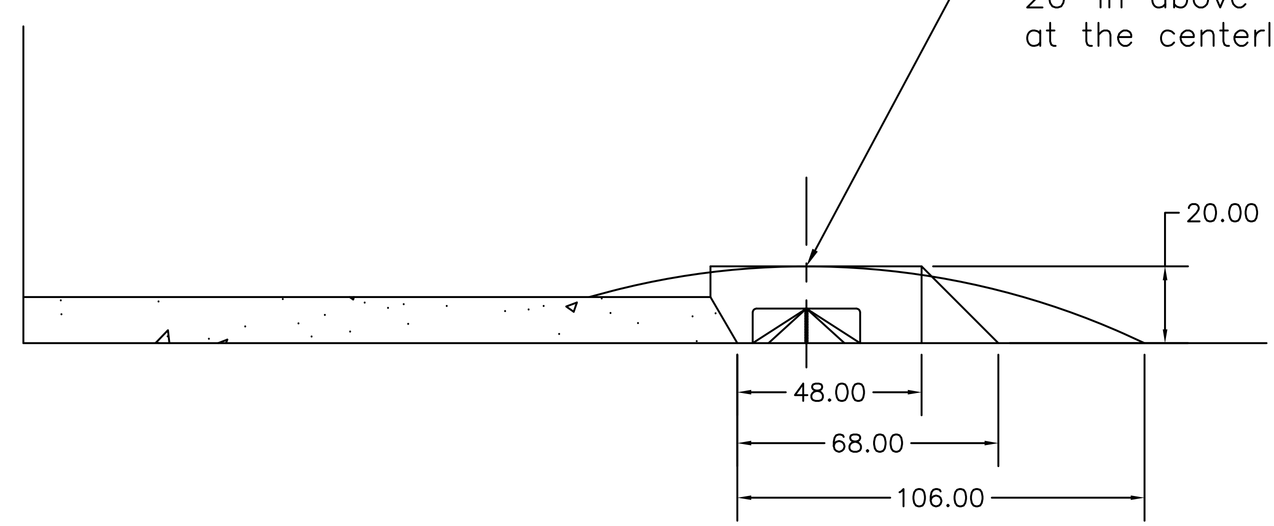
Note: 1) All dimensions given in prototype inches.
2) All elevations given in prototype feet.

NO.	DATE:	REVISION	DRAWN:	CHK. BY:

DRAWING SCALE:	DRAWN: M. Havice	DATE: 11/24/2021	PROJECT NO:
1:8	FILE NO: Plan	CHECKED:	

FIGURE 5-2
FLOOR CONE DETAILS
BEAUMONT
FREESE AND NICHOLS





Note: Drawing intended for
reference only. Not to be
used as a construction drawing.

Note: 1) All dimensions given in prototype inches.
2) All elevations given in prototype feet.

NO.	DATE:	REVISION	DRAWN:	CHK. BY:

DRAWING SCALE:	DRAWN: M. Havice	DATE: 11/24/2021	PROJECT NO:
1:50	FILE NO: Plan	CHECKED:	

FIGURE 5–3
FILLET / SPLITTER DETAILS
BEAUMONT
FREESE AND NICHOLS

5.3 Witness Testing

No formal witness test was held for this model. Video footage of both baseline and final documentation testing was included with the final report.

5.4 Final Documentation Testing

Final documentation tests were conducted for various operating conditions. The following modifications were in place:

- The vertical trough wall was revised to allow surface flow to enter the wet well.
- Floor cones were installed under each pump.
- Dividing floor splitters and sidewall fillets were installed in between the pumps and on the curved outer wall adjacent to the outer pumps.

Table 5-3 shows the final documentation test data.

Table 5-3 Summary Final Documentation Testing

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 1	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-4.7	3.1	7.0	1.6
Pump 2	15	none	none	none	none	none	No probe installed			0.6
Pump 3	15	none	none	none	none	none	No probe installed			1.0
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 2	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-3.1	4.2	3.6	0.6
Pump 2	0									
Pump 3	15	none	none	none	none	none	No probe installed			0.5
Pump 4	15	none	none	none	none	none	No probe installed			0.3

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 3	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-4.5	4.3	3.1	0.1
Pump 2	15	none	none	none	none	none	No probe installed			0.1
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 4	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	15	none	none	none	none	none	No probe installed			0.1
Pump 3	0									
Pump 4	15	none	none	none	none	none	No probe installed			0.1

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 5	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	19.5	none	none	none	none	none	-3.0	4.6	4.5	0.1
Pump 2	0									
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 6	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	0									
Pump 3	0									
Pump 4	19.5	none	none	none	none	none	No probe installed			0.1

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 7	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	0									
Pump 3	19.5	none	none	none	none	none	No probe installed			0.1
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 8	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	19.5	none	none	none	none	none	No probe installed			0.1
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 9	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-3.6	4.7	5.1	1.2
Pump 2	15	none	none	none	none	none	No probe installed			0.6
Pump 3	15	none	none	none	none	none	No probe installed			0.3
Pump 4	15	none	none	none	none	none	No probe installed			0.8

Comment: Water Level El. (-) 9.8 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
OFF DESIGN CONDITION
Flow on the wet well floor all downstream and stable
Vortex activity is minimized
Pre-swirl is low and stable

Note: Due to scheduling and availability, this model was constructed in a 4-ft basin, which allows a maximum water level of El. (-) 3.2 ft, which is the same elevation as the top of the vertical trough wall. In order to simulate operation at higher levels, a portion of the top of the center of the wall was removed to allow flow over the top. Testing showed that overall conditions remained stable and conditions at the pumps were unchanged.

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 10	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	15	none	none	none	none	none	-4.1	4.7	8.6	1.2
Pump 2	15	none	none	none	none	none	No probe installed			1.6
Pump 3	15	none	none	none	none	none	No probe installed			1.0
Pump 4	0									

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 11	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	15	none	none	none	none	none	No probe installed			0.8
Pump 3	15	none	none	none	none	none	No probe installed			0.7
Pump 4	15	none	none	none	none	none	No probe installed			0.1

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 12	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	15	none	none	none	none	none	No probe installed			0.3
Pump 3	15	none	none	none	none	none	No probe installed			0.6
Pump 4	0									

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 13	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	15	none	none	none	none	none	No probe installed			0.3
Pump 3	0									
Pump 4	15	none	none	none	none	none	No probe installed			0.1

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 14	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	19.5	none	none	none	none	none	-4.6	3.3	4.5	0.6
Pump 2	0									
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 15	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	19.5	none	none	none	none	none	No probe installed			0.2
Pump 3	0									
Pump 4	0									

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 16	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	0									
Pump 3	19.5	none	none	none	none	none	No probe installed			0.4
Pump 4	0									

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

Doc	Prototype Flow	Vortex Activity (I = Intermittent C = Constant)					Velocity & Turbulence (Vel = % of average)			Pre-Swirl
Test 17	(mgd)	Surface	Back wall	Side wall	Floor	Midflow	Min. Vel.	Max. Vel.	Max. Turb. %	Max (deg.)
Pump 1	0									
Pump 2	0									
Pump 3	0									
Pump 4	19.5	none	none	none	none	none	No probe installed			0.3

Comment: Water Level El. (-) 3.2 ft – Sump Invert El. (-) 25.2-ft.
Mods:
Floor cones installed under all pumps
Vertical trough wall revised – center portion at full height – sides lowered to allow flow over
Dividing floor splitters and sidewall fillets installed
Water level set at max allowable in basin
Center portion of the vertical trough wall lowered 12-in (prototype) to simulate water over the top
Overall conditions remain stable – conditions at the pumps are unchanged
Vortex activity is minimized
Pre-swirl is low and stable

6.0 CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

Initial testing showed that overall conditions in the trough baffle and in the wet well were turbulent and unstable. With no flow over the top of the vertical trough wall, all flow had to pass through the floor openings, which resulted in accelerated, high velocity flow on the floor approaching the pumps. The high velocity approach flow on the floor passed under the pumps and lifted vertically upward once behind the pumps. This phenomenon was observed for all operating conditions (1-3 pumps in operation). Stable, well developed floor vortex activity was observed under the pumps. Intermittent mid-flow vortex activity was observed forming between pumps when adjacent pumps were operating. Intermittent sidewall vortex activity was also observed forming on the curved outer walls adjacent to the outer pumps. Overall pre-swirl values were elevated and unstable, with frequent stalling and burst swirl observed.

Baseline testing indicated that submerged vortex activity and accelerated flow on the wet well floor were the two main hydraulic issues that required mitigation. Floor cones were installed under the pumps and were effective at preventing floor vortex activity. In addition, dividing floor splitters were installed in between the pumps and sidewall fillets were installed on the curved outer wet well walls adjacent to the outer pumps. The fillets and splitters were effective at preventing both sidewall and mid flow vortex activity. In order to reduce the approach velocity on the floor of the wet well, the vertical trough wall was revised by removing sections on each side of the wall. The center portion of wall remained unchanged. The openings on the side of the wall allowed water to pass through, thus reducing the velocity through the floor openings and the velocity on the wet well floor approaching the pumps. With the modifications installed, approach velocities on the wet well floor were significantly reduced and vortex activity was minimized.

6.2 Recommendations

It is recommended that the vertical trough wall be revised to allow surface flow to pass through notches cut into the sides of the wall. Floor cones should be installed under each pump. Dividing floor splitters should be installed between the pumps and sidewall fillets should be installed along the curved outer wall adjacent to the outer pumps. The recommended modifications can be seen in Figures 5-1 through 5-3.

7.0 REFERENCES

Hydraulic Institute Standards, 2018. American National Standard for Pump Intake Design 9.8. Hydraulic Institute, Parsippany, New Jersey, 07054-3802

Sweeney, C.E. and G.E. Rockwell, 1982. Pump Sump Design Acceptance through Hydraulic Model Testing. Proc. of the International Association for Hydraulic Research: Symposium on Operating Problems of Pump Stations and Power Plants. Amsterdam, the Netherlands, pp. 13-17, September 1982.